IER-161, BeRP Ball Reflected by Nickel Benchmark Evaluation

Benoît Richard, Jesson Hutchinson, Mark Smith-Nelson, Theresa Cutler, Avneet Sood

XCP-3, NEN-2

March the 26th, 2014

LA-UR-14-21929

Table of Contents

1. Introduction
2. Presentation
3. Experimental Techniques
4. Modelization
5. Comparison Experiment-Simulation
6. Conclusion & Future Work

Subcritical Neutron Noise Measurements

An appropriate tool to improve criticality safety assessments ...

- Subcritical neutron noise measurement techniques can infer the multiplication and the reactivity of a nuclear assembly
- Easy way to provide a continuous monitoring during operations
- Validation of the computational schemes used in criticality safety assessment
  - Nuclear data
  - Codes and Methods

... Need for new subcritical benchmarks in the ICSBEP Database

Objectives

Provide a benchmark evaluation based on a set of subcritical experiments involving the Berp ball reflected by nickel shells

- Reactivity range: from $k_{\text{eff}} = 0.79$ to $k_{\text{eff}} = 0.92$
- 7 configurations: from the bare Berp to the 3" reflected case
- Experiments performed in September 2012 at NCERC

The Berp Ball: Overview

- α-phase plutonium sphere (93.7 wt.% of Pu 239)
- 4.5 kg, 3.0” diameter
- Encapsulated in a SS 304 cladding
- Machined in 1980

- Previous experiments:
  - Be reflected critical experiment (PU-MET-FAST-038)
  - HEU reflected "Rocky Flats Shells" critical experiment (MIX-MET-FAST-013)
  - CSDNA subcritical noise measurements with polyethylene reflection (SUB-PU-MET-FAST-001) and nickel reflection

Nickel Shells

- 6 layers, each being 0.5” thick $\longrightarrow$ maximum thickness: 3.0”
- Each layer is composed of 2 combined shells

Benchmarked Quantities

- Must be deduced from well-known and fieldproven techniques
- Fundamental quantities having nevertheless a practical meaning
- Accessible and reliable uncertainty determination
- Must enable the discrimination without any ambiguity of each studied configuration

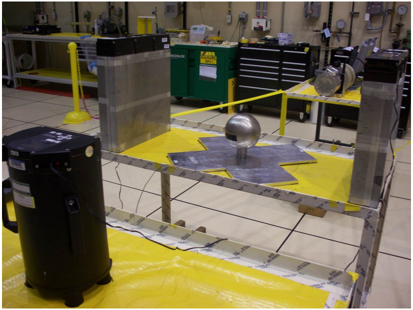
Selected quantities

- Directly deduced from the Feynman histogram:
  - R_1: singles asymptotic counting rate
  - R_2: doubles asymptotic counting rate
- M_l: leakage multiplication deduced from the Hage-Cifarelli formalism (based upon Feynman methodology)

Experimental Technique

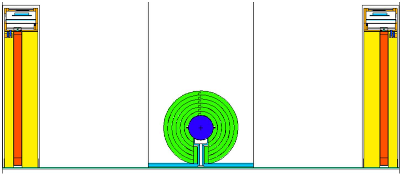
The Hage Cifarelli technique

- List mode data acquisition by two NPODs
- Construction of the Feynman histograms to deduce R_1, R_2 and R_3
- Assumption: the (α, n) source strength is negligible in front of the spontaneaous fissions source
- Knowing the distribution $p(\nu)$ for both source and induced fissions
- 3 equations $R_i = f(M_l, \epsilon, F_s)$
- Solve for M_l, ϵ and F_s



Codes and Methods

Steps	Experiment	Simulation
Source setting	Berp Ball	Fission source strength computed with MISC
List mode data acquisition	2 NPODs	Multiplication patch with MCNP5 $\longrightarrow$ detection events in He3 tubes
Solving Hage Cifarelli equations	ϵ deduced from calibration experiments $\rightarrow (M_l, F_s)$	F_s known (input parameter) $\rightarrow (M_l, \epsilon)$

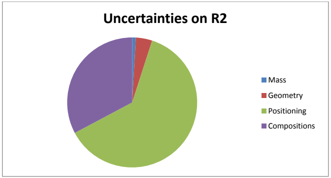


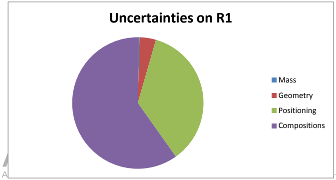
Sensitivity/Uncertainty Study - Experimental Data

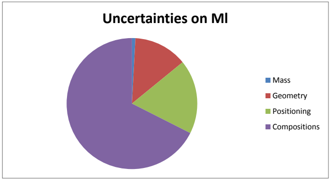
Illustration on the 3.0” thick reflected case

23 independent uncertainties on experimental data divided in 4 broad categories

	R_1	R_2	M_l
Combined uncertainties	2.02 %	2.79 %	0.72 %

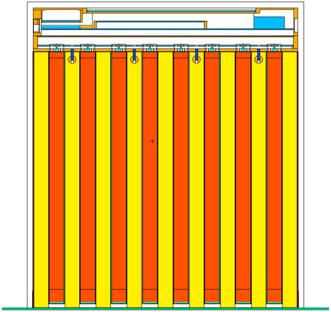


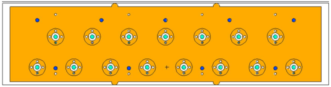




Benchmark Specifications for the NPODs

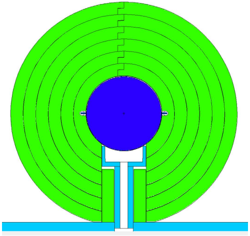
- Geometry:
  - Each piece is modeled
  - Dimensions taken from engineering drawings or measured directly
- He3 tubes features:
  - Taken from manufacturer specifications
  - Lack of information on composition, pressure, active region
  - Work in progress: calibration experiments with calibrated neutron sources





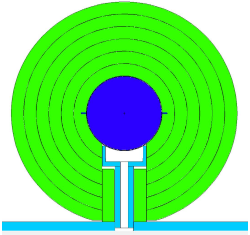
Models for the Berp Ball Assembly

Detailed model



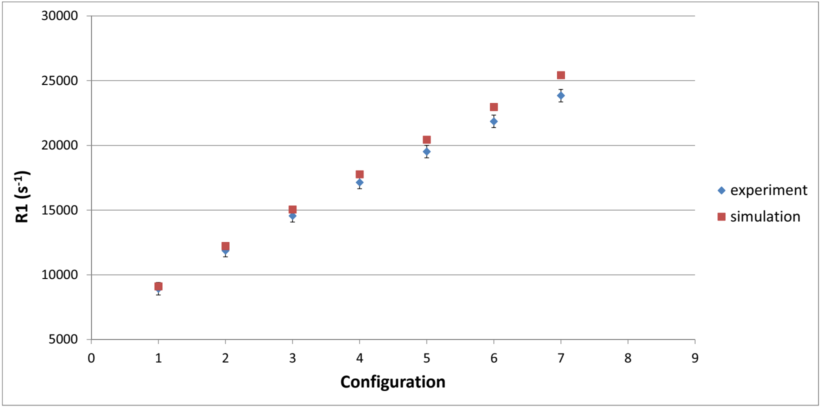
- As close as possible to engineering specifications

Simplified model

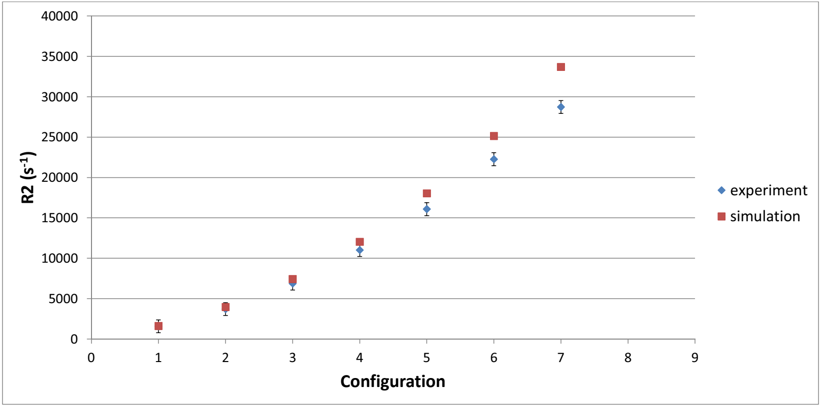


- Simplified geometry
- No impurities

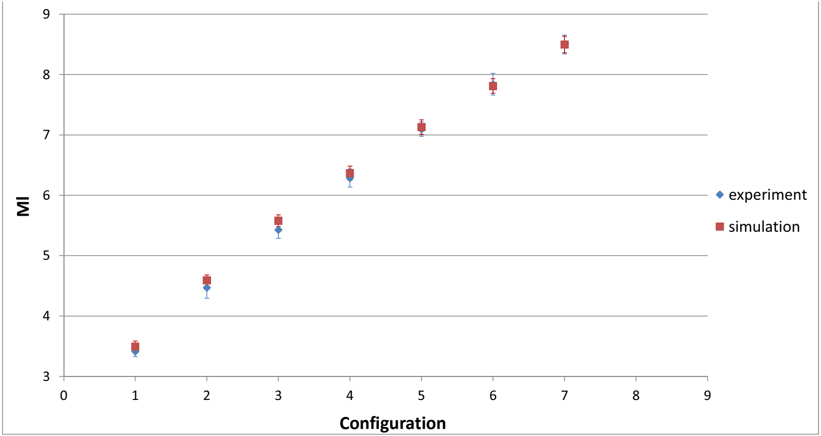
Comparison Experiment-Simulation on $\mathcal{R}_1$



Comparison Experiment-Simulation on $\mathcal{R}_2$



Comparison Experiment-Simulation on M_l



Conclusion & Future Work

- Criteria is met to make this benchmark acceptable
- Biases on R_1 and R_2 due to some missing information on He3 tubes
  - Pursue efforts with calibrated neutron sources
  - Investigations to find related specifications
- Uncertainty reduction by considering correlations effects
- Integration of a detailed model for the SNAP
- Study of the response given by the Gamma detector

Acknowledgments

This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the NNSA for the US DOE